NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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TWELFTH SEMIANNUAL REPORT OF ACTIVITIES AND EXPENDITURES

1 October 1968 - 31 March 1969

Submitted by

Electrical Engineering Research Laboratory
MILLIMETER WAVE SCIENCES

The University of Texas at Austin
Austin, Texas

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A. W. Straiton,
Laboratory Director

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I. INTRODUCTION

This is the Twelfth Semiannual Report of Activities of The University of Texas supported by NASA Grant NGL 44-012-006 (1 April 1968 through 31 March 1971). The grant for the purpose of investigating the millimeter wavelength electromagnetic radiation from bodies of the solar system is directed by Dr. A. W. Straiton and Dr. J. R. Cogdell.

II. MILLIMETER WAVE ASTRONOMICAL FACILITIES

A. Antenna

The status of the antenna calibration as of mid-January is summarized in our Technical Report NGL-006-69-1(1). The low value of efficiency (31%) of the antenna at 69.75 GHz, which was reluctantly quoted in our preceeding Semi-annual Report was found to be in error by subsequent tests and calculations, and the correct value of 58% appears in the calibration report.

The calibration program is ongoing and the following discussion is intended as an updating of the calibration report. In that report (pp. 22-23, 42-43) it is stated that we came to suspect that the antenna had significantly different foci in the two principal planes. This suspicion has since been confirmed through computer-aided calculations of the diffraction patterns of antenna apertures with quadratic phase errors. In this manner we have been able to simulate practically all the focusing vagaries of the antenna which are discussed in the report. This diagnosis is not yet complete, i.e. we have not yet determined the parameters which best fit the observed focusing behavior, but current estimates place the phase error magnitude at about 60° at $\lambda = 3.1$ mm and the preferred plane of orientation at 25° from the declination axis.

These studies are significant in several regards. First, they allow us to understand the behavior of our reflector and confirm that the focus we are operating at is the best obtainable under the current circumstances. Second, they will yield quantitative diagnostic information which will allow design of a compensating feed, as discussed in the calibration report (p. 43). Without such compensation, the antenna would be unuseable at its design frequency (140 GHz), where presumably small scale, random errors begin to degrade the antenna performance seriously.

Another area mentioned in the calibration report which has advanced since its publication is that of pointing errors evaluation. There (pp. 32ff) we discuss the sources of errors and give measurements of two of the four important effects. Recently another of the effects, declination axis non-orthogonality, have been evaluated and found to be negligible. This is gratifying since this type of error is uncorrectable. The fourth source of error, refraction, has been measured, and data have been partially analyzed. It seems clear that refraction errors due to difference between optical and radio refraction at millimeter wavelength have been over-estimated in the literature[2].

B. Receiver

Work has been done toward improving both the front end and the back end of the receiver. The mixer development program under Prof. Walser has progressed to the point where some Ge diodes are about to be fabricated.

These diodes are being made to perfect fabrication techniques and testing procedures and are not expected to yield improvement over current system performance. Pending success with the Ge diodes, the more difficult task of working in GaAs will be commenced.

In the area of data recording and processing, considerable product surveying has been done and some bids on this equipment have been received. The trade off between buying the system in subsystem form vs. buying the entire system from one vendor is being considered, and the equipment will be ordered within the next few weeks.

C. Physical Plant

During the reporting period, major maintenance work was done at the site. The entire exterior of the astrodome was sandblasted, primed, and repainted. The troublesome support rollers under the dome have been replaced by a set of specially designed rollers of superior strength.

Considerable work on the grounds and parking facilities were done. Also, some work was done toward strengthening the transient housing at the site.

The repairs and improvements enumerated in this section were unforeseen yet constitute a major expense during the reporting period. It is felt that no additional such needs will arise in the near future.

III. RADIO ASTRONOMY OBSERVATIONS

A. Venus

Observations of Venus are underway. Currently measurements are being made at 8.6 mm and 3.1 mm as weather permits. None of the data have been fully analyzed. Theoretical work in the data analysis techniques has been done and computer evaluation of the effects of finite planet disc size on the data have been made. These results are being included in our report, "The Use of Gaussian Functions in Radio Astronomy Measurements," to be published soon.

B. Sun

Dr. Yamashita completed his observations of the sun and returned to Nagoya University in Japan early in the reporting period. We have been in touch with him but have not yet received a report of his work on the sun or the moon. We have, however, received a preprint of a paper Dr. Yamashita has written on the effects of solar UV radiation on the ozone molecules in the lower ionosphere, as evidenced by diurnal variations in the sky emission temperature at millimeter wavelengths.

In the course of the program of observing Venus, the author was observing the sunrise at $\lambda = 3.1$ mm on 27 March. The purpose of these observations was to determine the opacity of the atmosphere on that date, as well as accumulate more data on sag and refraction. At approximately 1326 U.T., an impulsive outburst of the sun was observed. Figure 1 shows a drift scan of the sun which shows the outburst. A preliminary analysis of the data indicates that the outburst was in the decreasing stage by the time of the scan, and indeed decreased by a factor of five during the 30 seconds taken to scan the source in the data shown. Even so, the peak antenna temperature measured is 38,600°K on the data shown. This implies a source strength of 500×10^{-22} $w/Hz/m^2$, but a careful analysis of the data will surely indicate a much higher flux from the outburst. The intense part of the outburst lasted about five minutes and all trace of it was gone in about one hour.

The outburst source region was very small, less than .006°, and located about .002° from the west limb of the sun on the solar equator above a large center of sunspot activity. This is apparently the same sunspot associated with the auroral display the night of 23 March.

Two scans of the sun were made during the impulse phase of the outburst and the post-impulse phase was monitored for two hours. The time history of the outburst can be derived from these data. A preliminary report of this observation is being prepared for publication, and a careful analysis of the time history of the outburst will be published later. This is the first measurement of a solar flare at this frequency and should add greatly to knowledge of the physics of these events.

C. Crab Pulsar Measurement

Early in February at the suggestion of Dr. Bruce Ulrich of the Astronomy Department, the author collaborated with the aforementioned in an attempt to observe the pulsar in the Crab Nebula at millimeter wavelengths. The object of the measurement was to measure the flux of the object and its phase relative to the optical pulse. The measurements was made possible by the fact that Warner and Nather of the Astronomy Department were making simultaneous optical measurements of the pulsar on the 82 inch reflector at McDonald Observatory.

The Crab Pulsar is distinguished by having the shortest known period, 33 milliseconds, and is the only pulsar which has been detected optically. The time structure of the flux is shown in Figure 2. Our hope of detection rested upon being able to pull the sharp pulse out of the noise with long periods of integration. The known (at the time) average flux at radio and optical frequencies are shown by the end points in Figure 3. The arrow marks our frequency of 35 GHz and the intercept with the straight line implies a flux of around one flux unit (10^{-26} watt/m^2Hz). This was close to our limit and encouraged us to attempt the measurement.

The system we used is shown in Figure 4. The borrowed Computer of Average Transients (C. A. T.) divides the pulsar period into equal time segments and stores a count proportional to the signal in each time bin in an array counter. In all, 400 channels were used and, due to the relation of the pulsar period to the sweep period of the C. A. T., these recorded approximately 3.6 pulsar periods. The C. A. T. was triggered by a pulse furnished by Nather from the McDonald clock plus his digital vernier equipment.

The data were gathered in three forty minute tracks on the pulsar. Pointing was confirmed before and after each track by detection of the Tausus A source by conventional means. A total of 216,000 pulses were averaged and the results are shown in Figure 5. The count in the time bin corresponding to the optical pulse is the highest but is not significantly higher than the noise. Although the probability of such a high point is small (10%), we decided that it was not significant enough to constitute detection. The alternative was to set an upper limit and these are shown for different confidence levels on Figure 5. The 90% confidence level value, 2.1 F.U., falls on the straight line in Figure 3 and rules out curves which are concave downward. A more sophisticated data analysis based upon autocorrelation might dig the signal out of the noise, but receiver improvements would be more important. Current plans are to try again in September.

IV. REPORTS AND PUBLICATIONS

Technical Reports

1a Tolbert, C. W., A. W. Straiton and L. C. Krause, "A 16-Foot Millimeter Wavelength Antenna System, Its Characteristics and Its Applications," NsG-432, Technical Report No. 1, EERL Report No. I-01, The University of Texas, 15 March 1964.

2a Tolbert, C. W. and A. W. Straiton, "An Investigation of 35 Gc, 70 Gc, and 94 Gc Cytherean Radiation," NsG-432, Technical Report No. 2, EERL Report No. I-02, The University of Texas, 15 October 1964.

3a Cogdell, J. R., "Calibration Program for the 16-Foot Antenna," NGL 44-012-006, Technical Report No. NGL-006-69-1, The University of Texas, 15 January 1969.

Publications

1b Galloway, D. G. and C. W. Tolbert, "A Germanium Bolometer Detector for Millimeter Wavelength Thermal Energy," Rev. Sci. Instr., Vol. 35, No. 5, pp. 628-630, May 1964, Additament, July 21, 1964.

2b Tolbert, C. W., L. C. Krause and A. W. Straiton, "Solar Radiation at 3.2 mm During the 20 July 1963 Eclipse," Astrophy. J., Vol. 140, No. 1, pp. 306-312. July 1, 1964.

3b Tolbert, C. W. and A. W. Straiton, "An Investigation of 35 Gc, 70 Gc, and 94 Gc Cytherean Radiation," Nature, Vol. 204, No. 1242, 26 December 1964.

4b Tolbert, C. W., A. W. Straiton and L. C. Krause, "A 16-foot Diameter Millimeter Wavelength Antenna System, Its Characteristics and Its Applications," IEEE Trans on Antennas and Propagation, Vol. AP-13, No. 2, pp. 225-229, March 1965.

5b Tolbert, C. W., "Millimeter Wavelength Spectra of the Crab and Orion Nebulae," Nature, Vol. 206, No. 4991, pp. 1304-1307, 26 June 1965.

6b Tolbert, C. W., "Observed Millimeter Wavelength Brightness Temperatures of Mars, Jupiter and Saturn," Astron. J., Vol. 71, No. 1. pp. 30-32, February 1966.

7b Takahashi, K., "An Investigation of Solar Emission at Frequencies of 35 Gc, 70 Gc and 94 Gc with a 4.88 Meter Diameter Telescope," The Astrophy. J., Vol. 148, May 1967.

8b Clardy, D.E. and A. W. Straiton, "Radiometric Measurements of the Moon at 8.6 mm and 3.2 mm Wavelengths," The Astrophy. J., Vol. 154, November 1968, pp. 775-782.

9b Jelks, E. C., and J. R. Cogdell, "Jovian Emission at 8.6 mm," Astrophy. J., letter to the Editor.

Theses

1c Galloway, D. G., "An Evaluation of the Texas Instruments' Germanium Bolometer at Millimeter Radio - Frequency Wavelengths," Master of Science in Electrical Engineering Thesis, The University of Texas, January 1964.

2c Vivian, R. A., "A Low-Noise 100-MC Bandwidth Transistorized I-F Amplifier for Radio Astronomy," The University of Texas, Master of Science in Electrical Engineering Thesis, August 1964.

3c Sizelan, J. H., "Radio Astronomy Signal Spectrum Analyser," Master of Science in Electrical Engineering Thesis, The University of Texas, September 1965.

4c Clardy, D. E., "Lunar Millimeter-Wavelength Radiation and Thermal Model," Ph.D., The University of Texas at Austin, January 1968.

5c Jelks, E. C., "A Measurement of the Blackbody Disk Temperature of Jupiter at 8.6 Millimeter Wavelengths," Master of Science in Electrical Engineering Thesis, The University of Texas at Austin, August 1968.

V. BUDGET AND EXPENDITURES

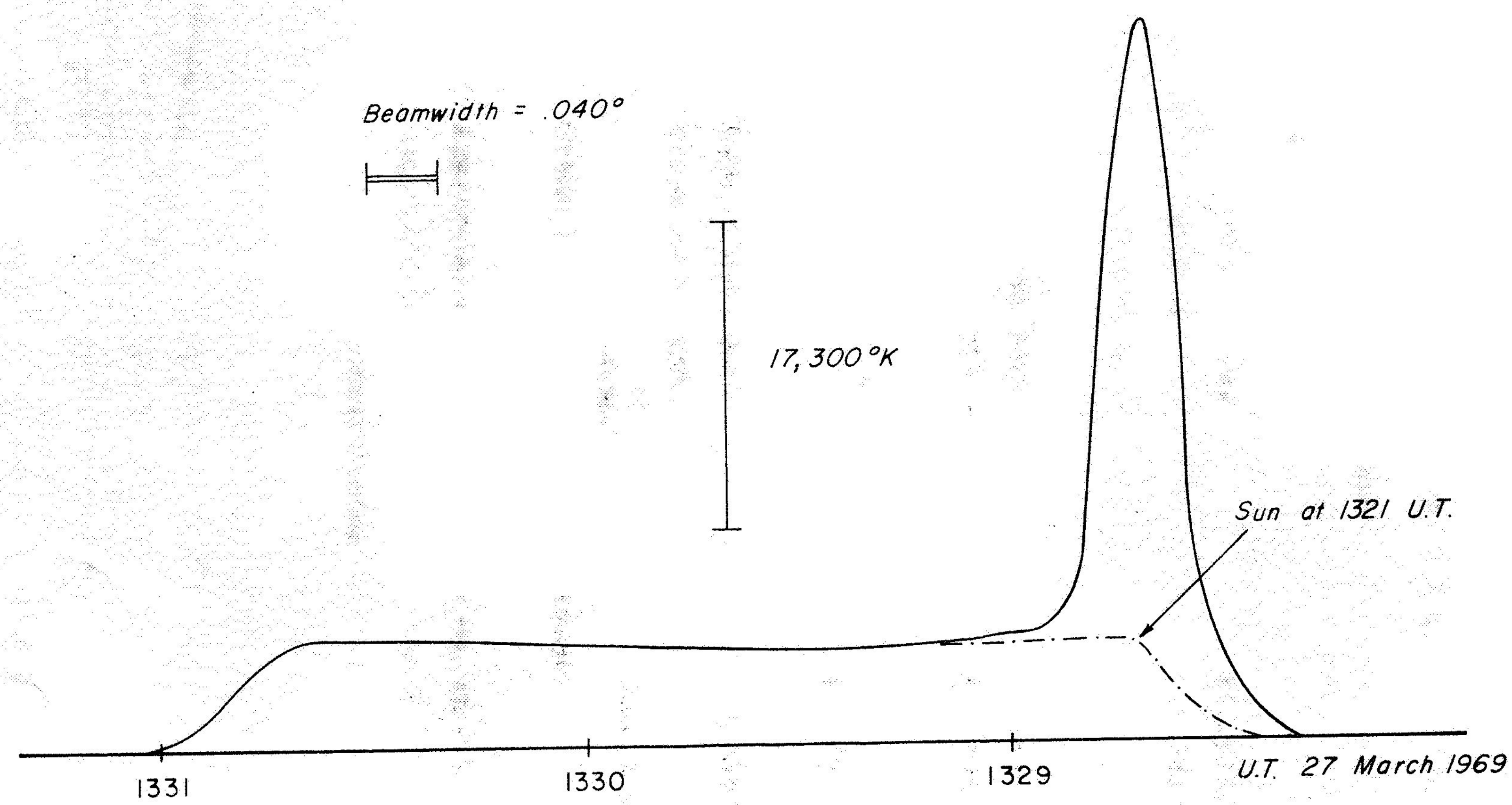
The following expenditures between 1 October 1968 and 31 March 1969 have been made from the subject grant:

Salaries and Wages		
Professional	$11,222.15	
Student	2,992.87	
Supporting Services	1,746.86	
Total		$15,961.88
Instruments (Major)	----	
Instruments (Minor)	$ 3,499.90	
Total		$ 3,499.90
Travel, Communications and Reports	$ 1,943.83	
Miscellaneous	5,238.29	
Repaint Astrodome	2,369.00	
Overhead and Other Indirect Costs	6,741.76	
Total		$16,292.88
Grand Total (1 October 1968 through 31 March 1969)		$35,754.66

Appropriated (1 April 1969 - 31 March 1970)

Appropriated (1 April 1970 - 31 March 1971)

Step Funded



DRIFT SCAN OF MILLIMETER SOLAR OUTBURST, $\lambda = 3.1$ mm

FIG. 1.

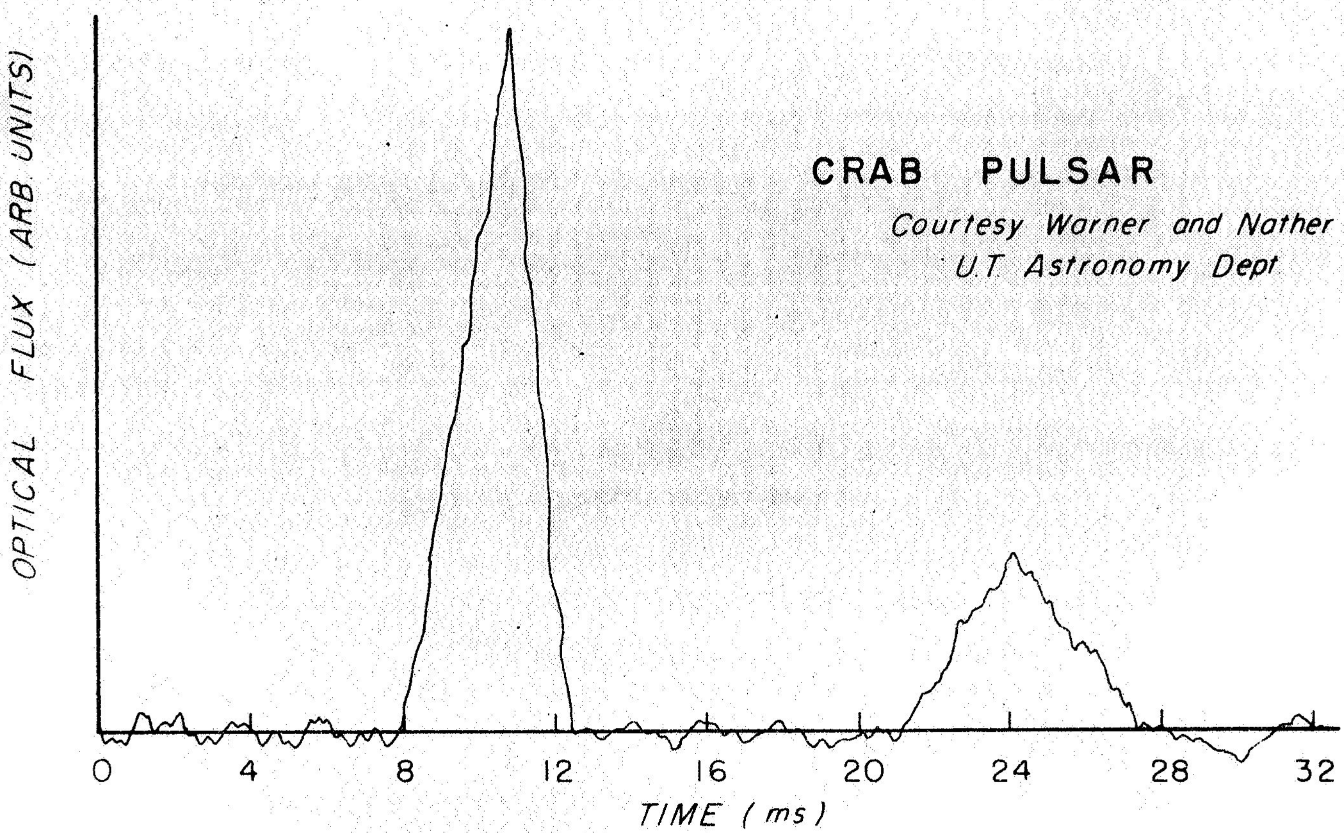

CRAB PULSAR
Courtesy Warner and Nather
U.T. Astronomy Dept
OPTICAL FLUX (ARB UNITS)
0 4 8 12 16 20 24 28 32
TIME (ms)

FIG. 2.

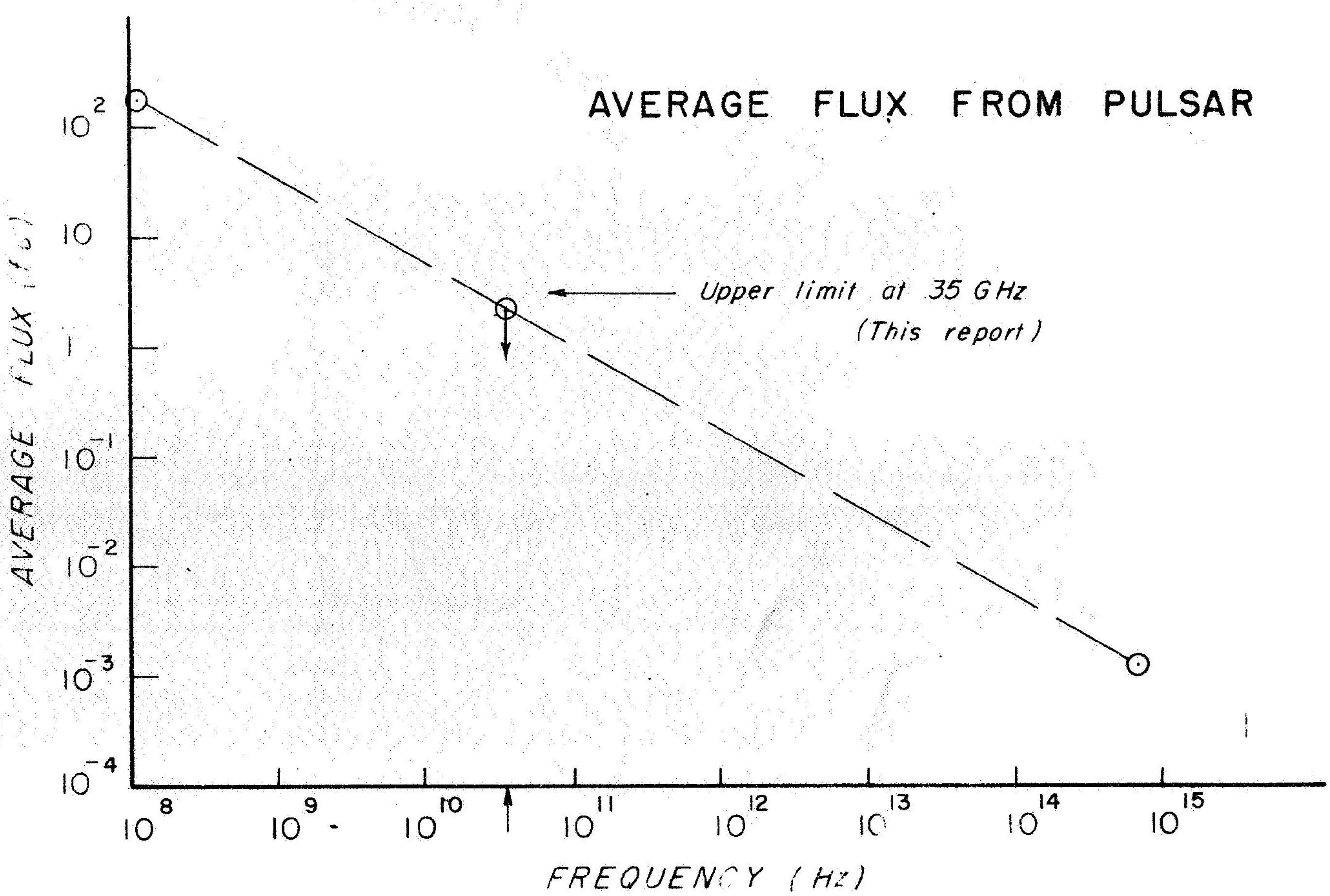
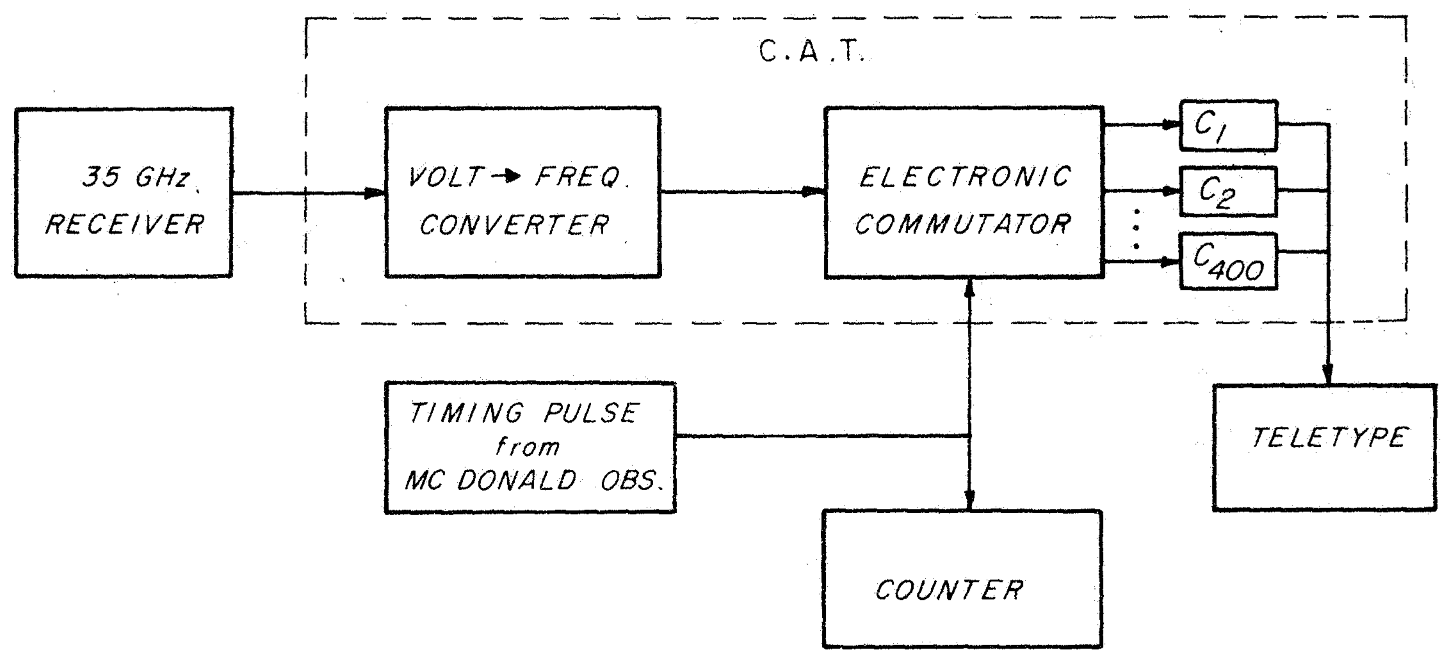
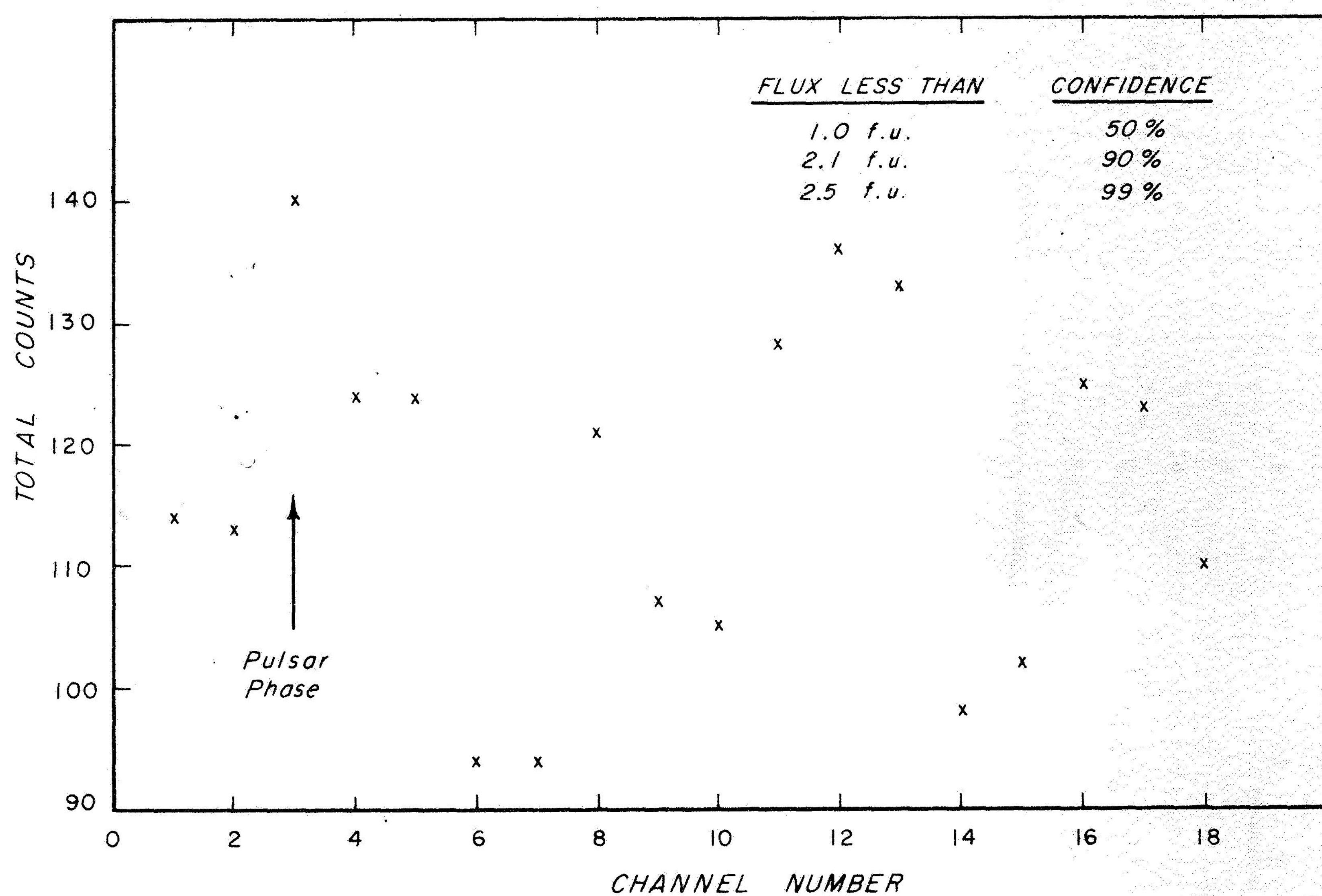

AVERAGE FLUX FROM PULSAR
Upper limit at 35 GHz
(This report)
AVERAGE FLUX
10^2 10 1 10^{-1} 10^{-2} 10^{-3} 10^{-4}
10^8 10^9 10^{10} 10^{11} 10^{12} 10^{13} 10^{14} 10^{15}
FREQUENCY (Hz)

FIG. 3



PULSAR MEASUREMENT SYSTEM

FIG. 4.



PULSAR DATA

FIG. 5.

REFERENCES

1. J. R. Cogdell, "Calibration Program for the 16-Foot Antenna," Electrical Engineering Research Laboratory, The University of Texas at Austin, Technical Report NGL-006-69-1, 15 January 1969.

2. Aarons, J., W. R. Barron, and J. P. Castelli, "Radio Astronomy Measurements at VHF and Microwaves," Proc. IRE, Vol. 46, Jan. 1958, pp. 325-333.